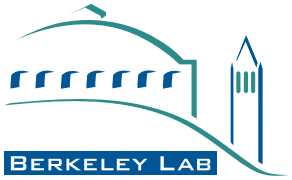

Evaluation of Arizona's Enhanced I/M Program

presentation to NRC Committee to Review MOBILE Model
March 4, 1999

by

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Using Out-of-Program Data to Evaluate I/M

- **Benefits of out-of-program testing**
  - —unscheduled testing minimizes "clean for a day" effect (temporary adjustments to pass I/M test)
  - —needed to measure total vehicle emissions (ineligible vehicles)
  - —can identify and measure failed vehicles still driving in I/M area
- **Out-of-program test methods**
  - —voluntary roadside pullover tests
    - expensive
    - recruitment bias
    - enables visual inspection
  - —remote sensing at controlled driving mode sites
    - relatively inexpensive
    - no bias if no penalty for driving by sensor
    - potential for remotely measuring evaporative HC?

IM240 Data used in Arizona Evaluation

- **Centralized, biennial IM240 for MY81 and newer vehicles**
- **850,000 vehicles with initial IM240 between January 1996 and June 1997**
  - **—emissions of vehicles fast-passed or fast-failed extrapolated to full-test equivalents**

IM240 Fleet Emission Reductions Compared to MOBILE5 Prediction

	Vehicles	CO	HC	NOx
MOBILE5*		16.2%	16.9%	16.7%
1995 AZ IM240 (random sample)*	7,600	16.2%	14.3%	7.6%
1996-97 AZ IM240 (all tests)	451,000	14.5%	14.0%	7.1%
1996-97 AZ IM240 (random sample)	9,000	13.4%	15.1%	7.6%
Percent of MOBILE5 emission reduction:				
1995 AZ IM240 (random sample)		100%	85%	46%
1996-97 AZ IM240 (all tests)		90%	83%	43%
1996-97 AZ IM240 (random sample)		83%	89%	46%

* Analysis of the Arizona IM240 Test Program and Comparison with the TECH5 Model, Glover and Brzezinski, May 1997.

Remote Sensing Data used in Arizona Evaluation

- 4.0 million remote sensing readings of 1.2 million vehicles between January 1996 and August 1997 (originally used for identifying high emitters)
  - —over 100 remote sensing sites
  - —CO and HC emissions only (no NOx)
  - —limitations with Hughes remote sensing data:
    - emissions measurements
    - vehicle speed/acceleration measurements
    - inefficient site selection
    - matching measurements to vehicles
- 451,000 vehicles with both IM240 and remote sensing data

Remote Sensing Data Compare Well with IM240 Data (for CO)

- **Average CO emissions by MY, as measured by remote sensing and IM240 on the same vehicles, correlate well (r^2=0.99)**

- **Average HC emissions of MY91+ vehicles do not correlate**
  - **—IM240 HC emissions too low?**
    - **due to method to adjust fast pass/fast fail IM240s to full-IM240 equivalent emissions?**

      (but adjusted average emissions by MY from FP/FF vehicles correlate very well with random 2% sample of full IM240s)
  - **—or remote sensing HC emissions too high?**
    - **due to negative HC readings "zeroed out"?**
    - **due to bias in remote sensing measurement of low HC values?**

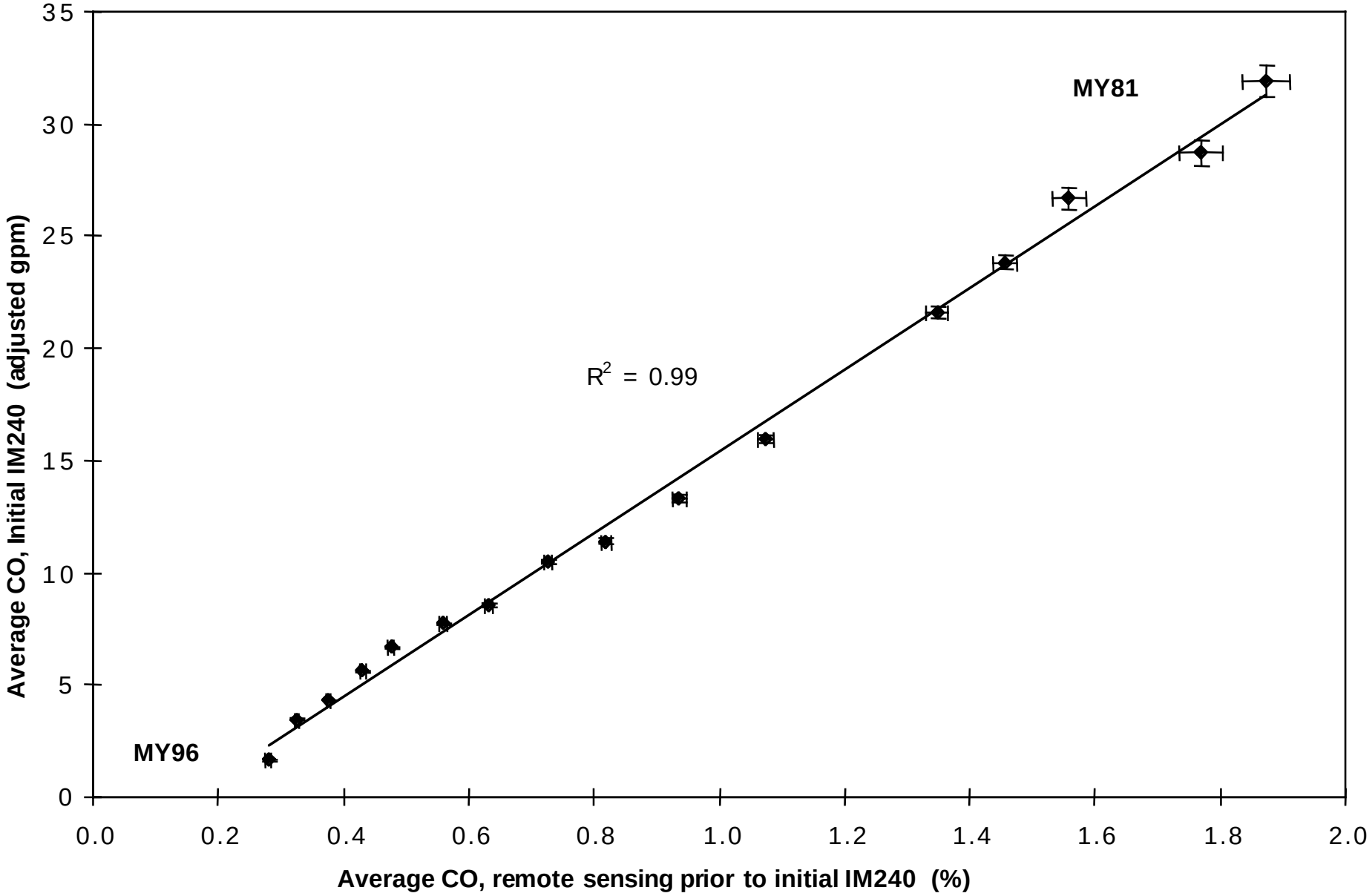
      (evaluation by RSTi found Hughes sensor biased high for HC and CO)
    - **due to poor remote sensing site selection?**

      (half of vehicles with speed measurements were decelerating)

- **No NOx measurements**

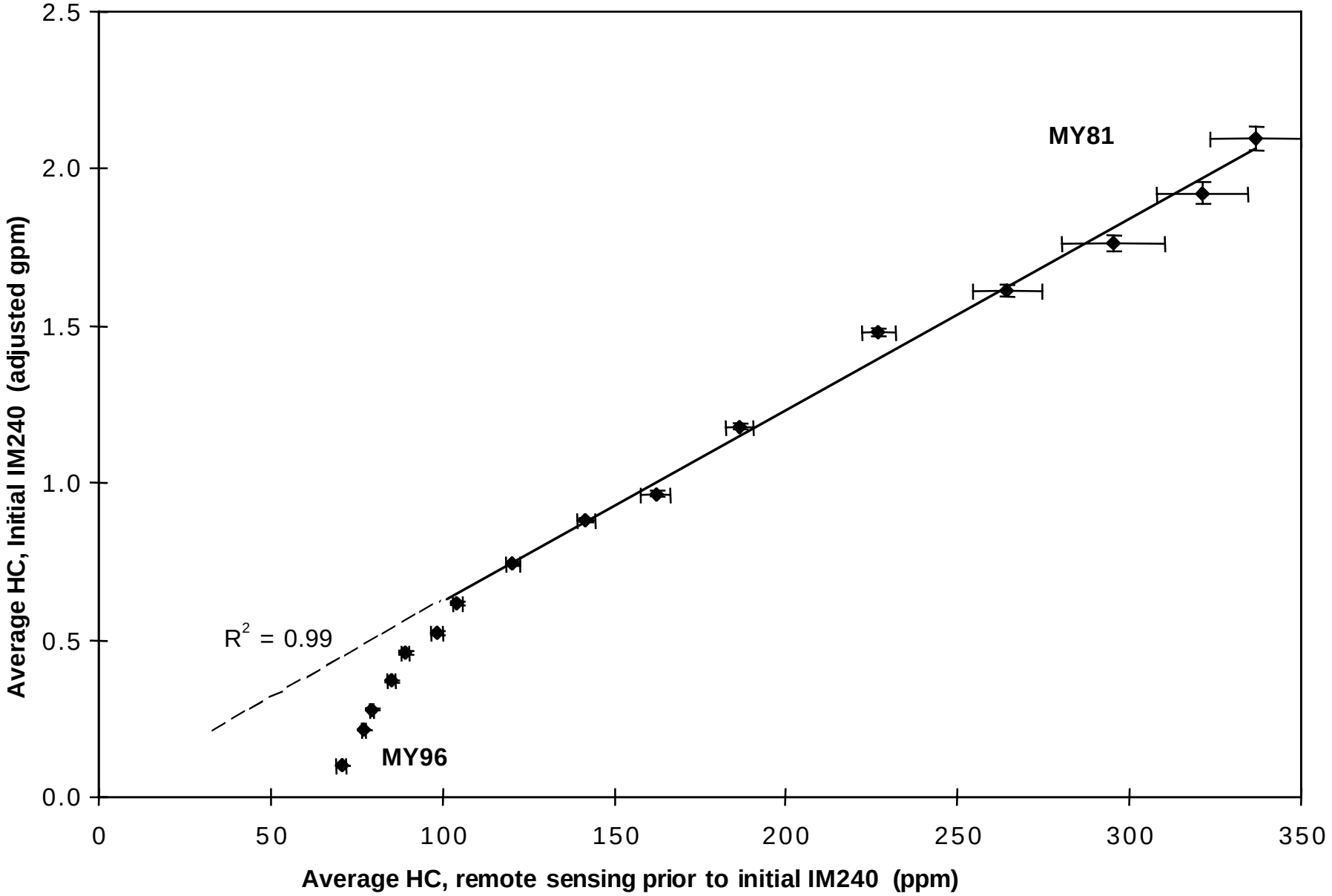
Average Remote Sensing and IM240 CO by MY

168,000 vehicles,1996-97 Arizona



Average Remote Sensing and IM240 HC by MY

168,000 vehicles, 1996-97 Arizona



Analyzed 3 Groups of Vehicles, Based on I/M Results

- **"Initial Pass"**
  - —passed initial I/M test, no second I/M test
- **"Final Pass"**
  - —failed initial I/M test, passed final I/M test
  - —includes vehicles that passed retest without any repairs
- **"Disappearing"**
  - —failed initial I/M test, no final passing I/M test
  - —includes vehicles with no second I/M test, and those that failed subsequent I/M test
  - —includes waived vehicles (unidentified; roughly 4% of failed vehicles)

Vehicle and Emission Distributions by I/M Result

			Percent of Vehicles Studied		
I/M Result	**Vehicles**	**Percent of All**	**Vehicles**	**Pre-I/M CO**	**Post-I/M CO**
Initial Pass	373,954	82.9%	90.6%	65%	76%
Final Pass	26,009	5.8%	6.3%	22%	9%
Disappearing	12,880	2.9%	3.1%	14%	15%
Multiple Initial Tests	25,099	5.6%			
Pass Tailpipe, Fail Visual	13,058	2.9%			
Total	451,000	100.0%	100.0%	100%	100%
Of All Vehicles Studied:					
Initial and Final Pass	399,963		96.9%	87%	85%
Disappearing	12,880		3.1%	14%	15%
Total	412,843		100.0%		
Of All Initial Fails:					
Final Pass	26,009		66.9%	61%	38%
Disappearing	12,880*		33.1%*	39%	62%
Total	38,889		100.0%		

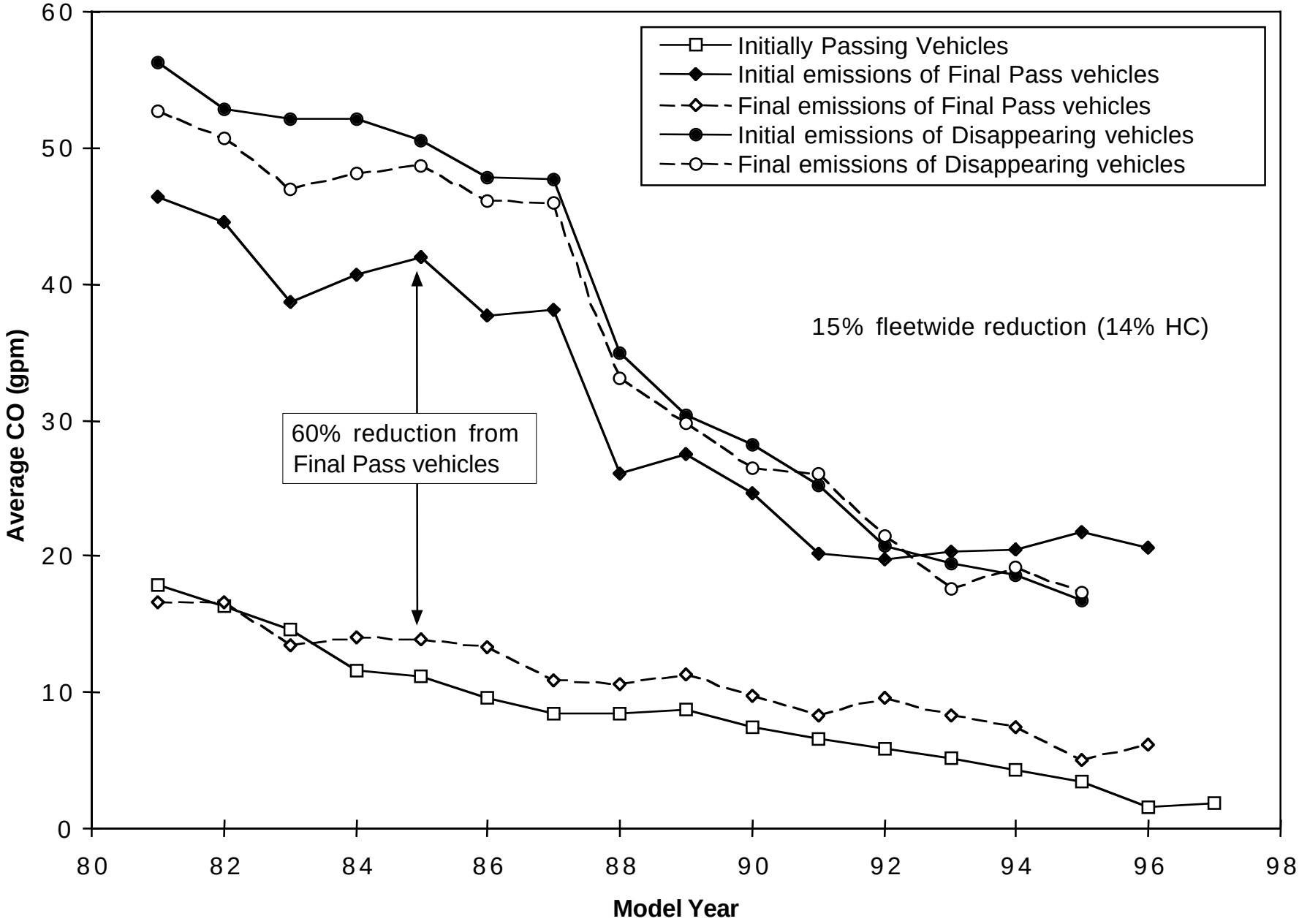
*** 4% are waived**

IM240 Data Show Big Emission Reductions...

- **Fleet emissions are reduced by 15% for CO (and 14% for HC)**
- **Final Pass vehicle emissions are dramatically reduced, by 60%, for CO and HC**
- **But Final Pass vehicles still emit slightly more than Initial Pass vehicles**
- **No Final Pass, or Disappearing, vehicles see small emission reductions due to one or two rounds of repairs**

Average CO gpm by MY and I/M Result

1996-97 Arizona IM240

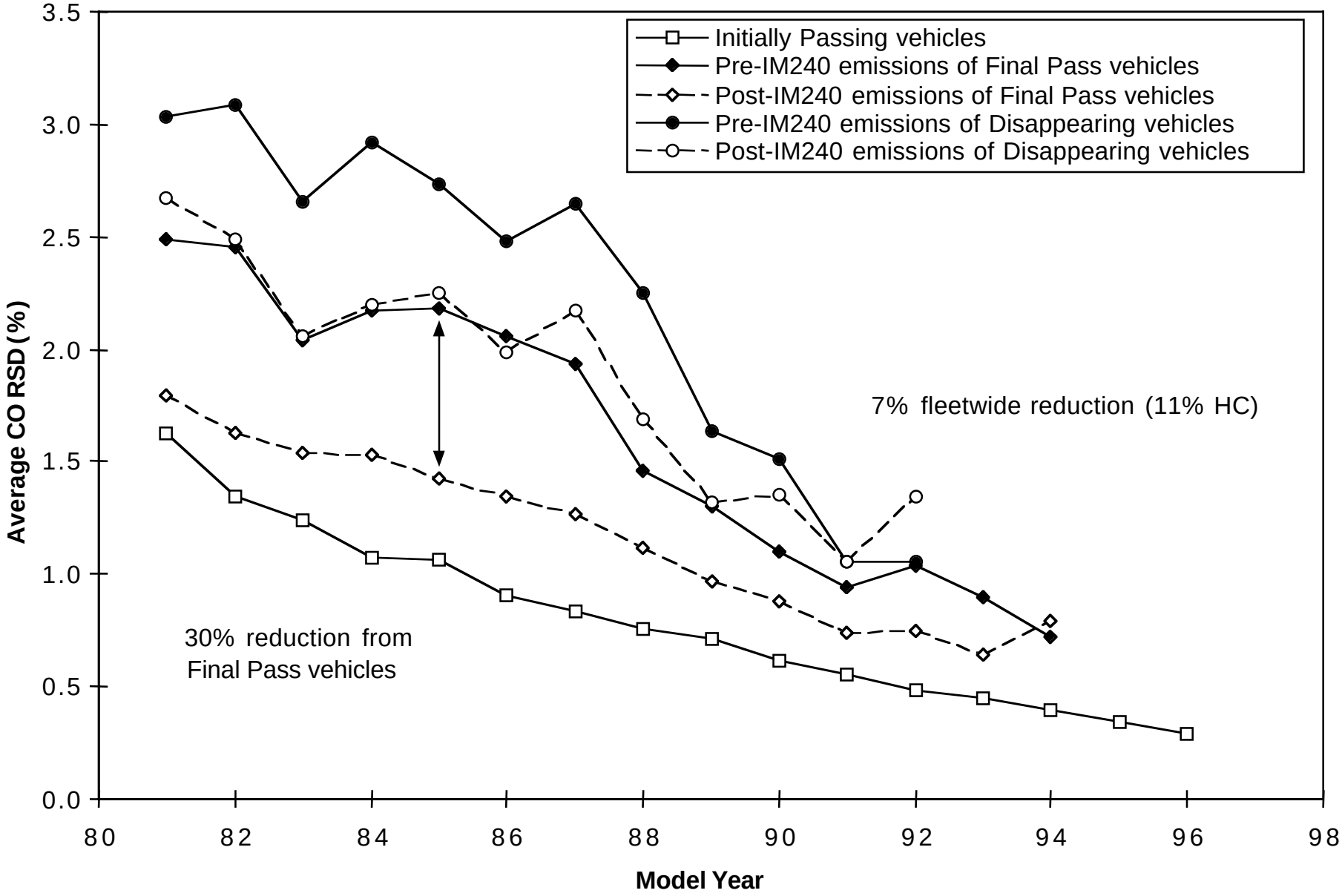


... but RSD Shows Much Smaller Reductions

- **Comparison of average remote sensing emissions up to 90 days before the initial IM240 with remote sensing emissions up to 90 days after final IM240**
- **Fleet emissions only reduced by 7% for CO (half as much as measured by IM240); by 11% for HC**
- **Emissions from Final Pass vehicles reduced only 30% for CO, 40% for HC**
- **Remote sensing sees larger difference in emissions from Final Pass vehicles and Initial Pass vehicles**
- **Remote sensing sees bigger reduction in emissions from Disappearing vehicles**

Average RSD CO by MY and I/M Result

Up to 90 days before and after I/M test, 1996-97 Arizona Remote Sensing

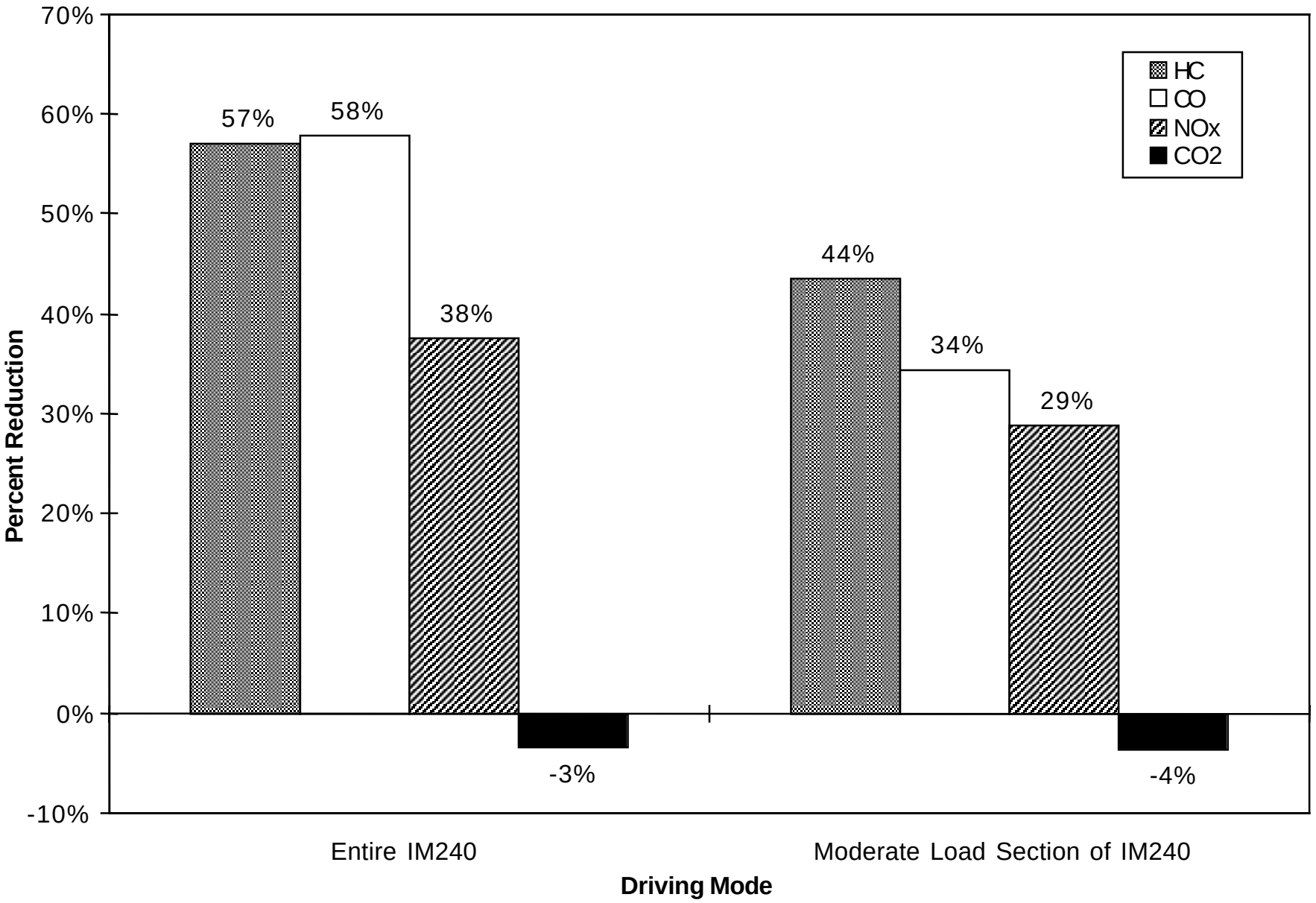


Discrepancy between IM240 and RSD Results Explained in Part by Vehicle Operation

- **Is repair effectiveness sensitive to vehicle driving mode? The IM240 is not a vigorous driving cycle, whereas RSD units are sited at locations where vehicles are under moderate loads, to get a strong enough emissions signal**
- **Analyzed second-by-second data on 1,000 vehicles with full IM240 tests before and after repair**
- **Divided IM240 trace into modes of distinct vehicle operation, including the moderately loaded portion of the IM240**
- **Repairs reduce CO emissions over the entire IM240 by nearly 60%; however emissions over the moderate load portion are reduced by only 34% (similar to RSD results)**
- **Much of the difference in repair effectiveness as measured by IM240 and RSD may be attributable to different vehicle operating conditions under the two tests**

Emission Reductions Due to IM240 Repairs

1080 Vehicles, 1996 Arizona IM240

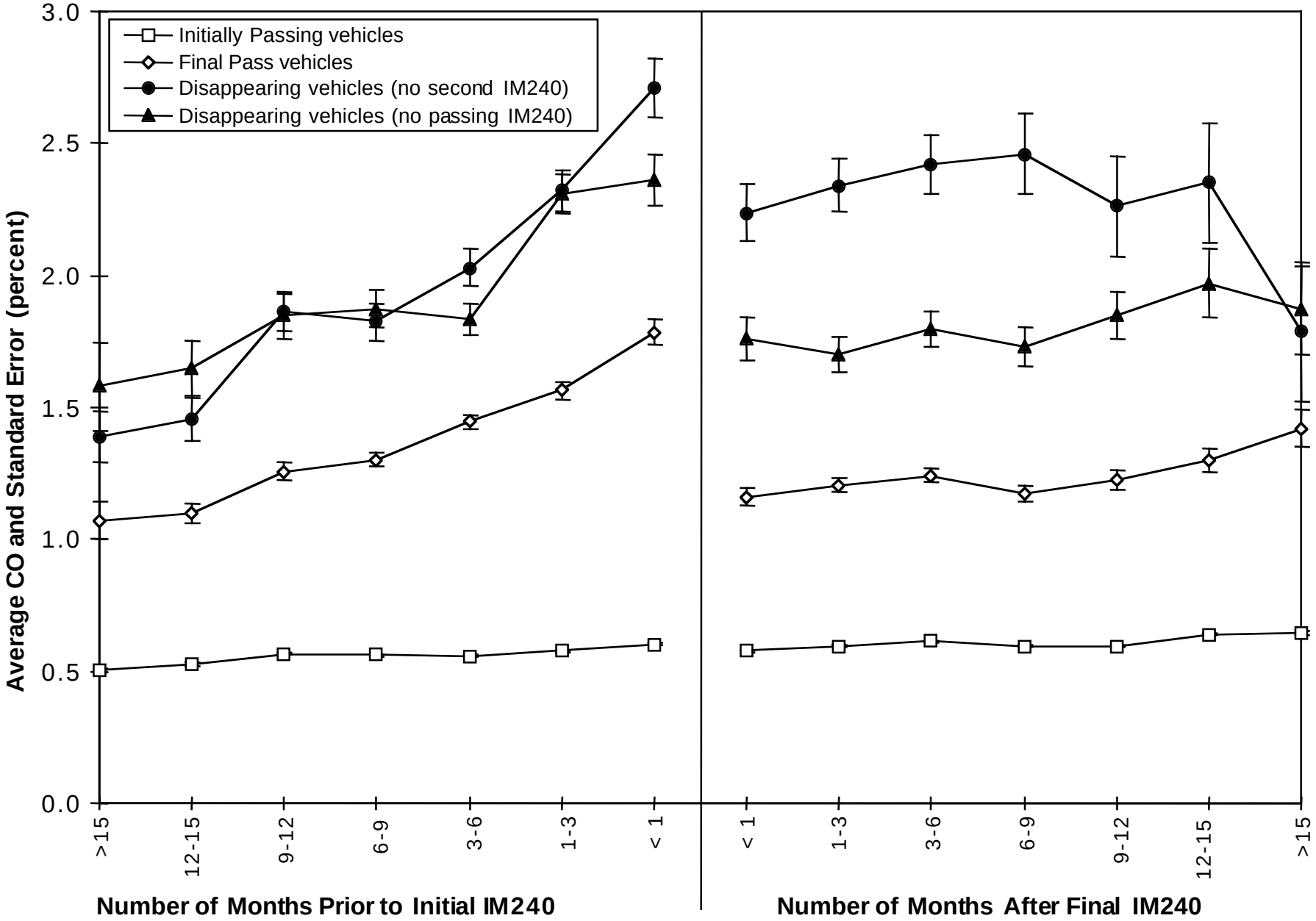


Repair Effectiveness Depends on when Emissions Measured

- **Remote sensing emissions increase as vehicle gets closer to initial I/M test**
- **Big initial emissions reduction due to passing I/M test**
- **Emissions increase as vehicle gets further from final I/M test**

Average CO RSD Emissions by Time Period

1996-97 Arizona Remote Sensing



Repair Effectiveness, as Measured by RSD, Diminishes over Time

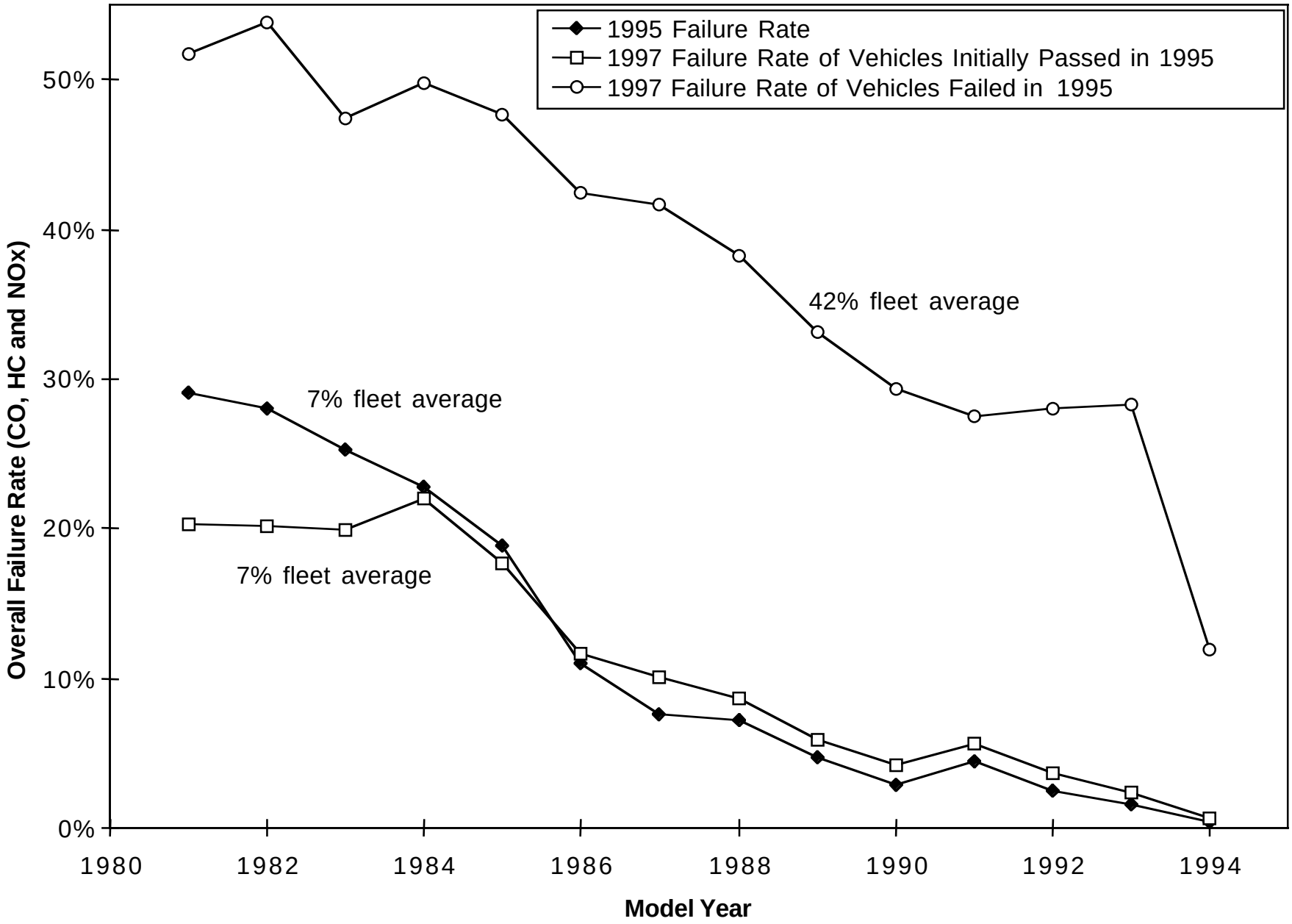
	Emission Reductions	
IM240	**CO**	**HC**
Fleet	15%	14%
Final Pass Vehicles	64%	61%
Remote Sensing		
up to 1 month after I/M		
Fleet	12%	19%
Final Pass Vehicles	36%	46%
3-6 months after I/M		
Fleet	9%	14%
Final Pass Vehicles	32%	35%
12-15 months after I/M		
Fleet	6%	14%
Final Pass Vehicles	28%	24%

Long-Term Benefit of Repairs

- **Analyzed 1997 results of vehicles tested in 1995 in Arizona. Cutpoints were not changed during this period**
- **42% of vehicles that were repaired in 1995 fail again in 1997. The percent of "repeat offenders" ranges from 10% for MY94 to 50% for MY81**
- **Vehicles that initially passed in 1995 fail at the same rate in 1997 as the overall 1995 failure rate (7%)**
- **The same vehicles are failing subsequent I/M tests, either because of insufficient initial repair or a different component failing**

Overall I/M Failure Rates by Test Year and MY

1995 and 1997 Arizona IM240

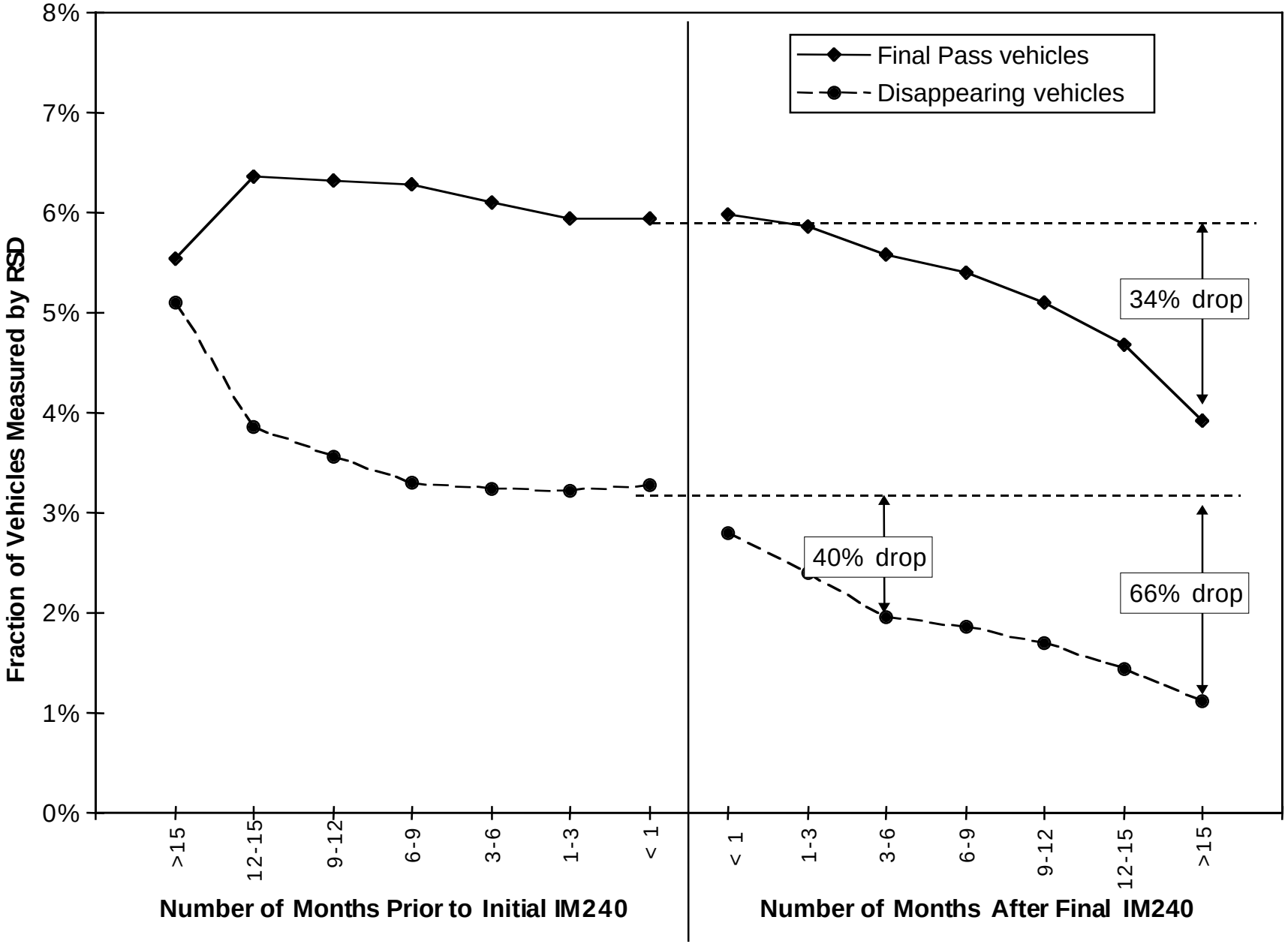


What Happens to Disappearing Vehicles?

- **Ideally, Disappearing vehicles are scrapped or otherwise no longer operate in I/M area**
- **Calculated the distribution of remote sensing readings by I/M result and time period to see if the fraction of Disappearing vehicles in the RSD "fleet" decreases more rapidly than the fraction of Final Pass vehicles**
- **Remote sensing data show that 40% of Disappearing vehicles are no longer driven in I/M area 6 months after I/M test**
- **However, one-third of Disappearing vehicles continue to be driven in I/M area even 15 months after I/M test**
- **In contrast, about two-thirds of Final Pass vehicles continue to be driven in I/M area 15 months after I/M test**

Fraction of Vehicles by I/M Result and Time Period

1996-97 Arizona Remote Sensing

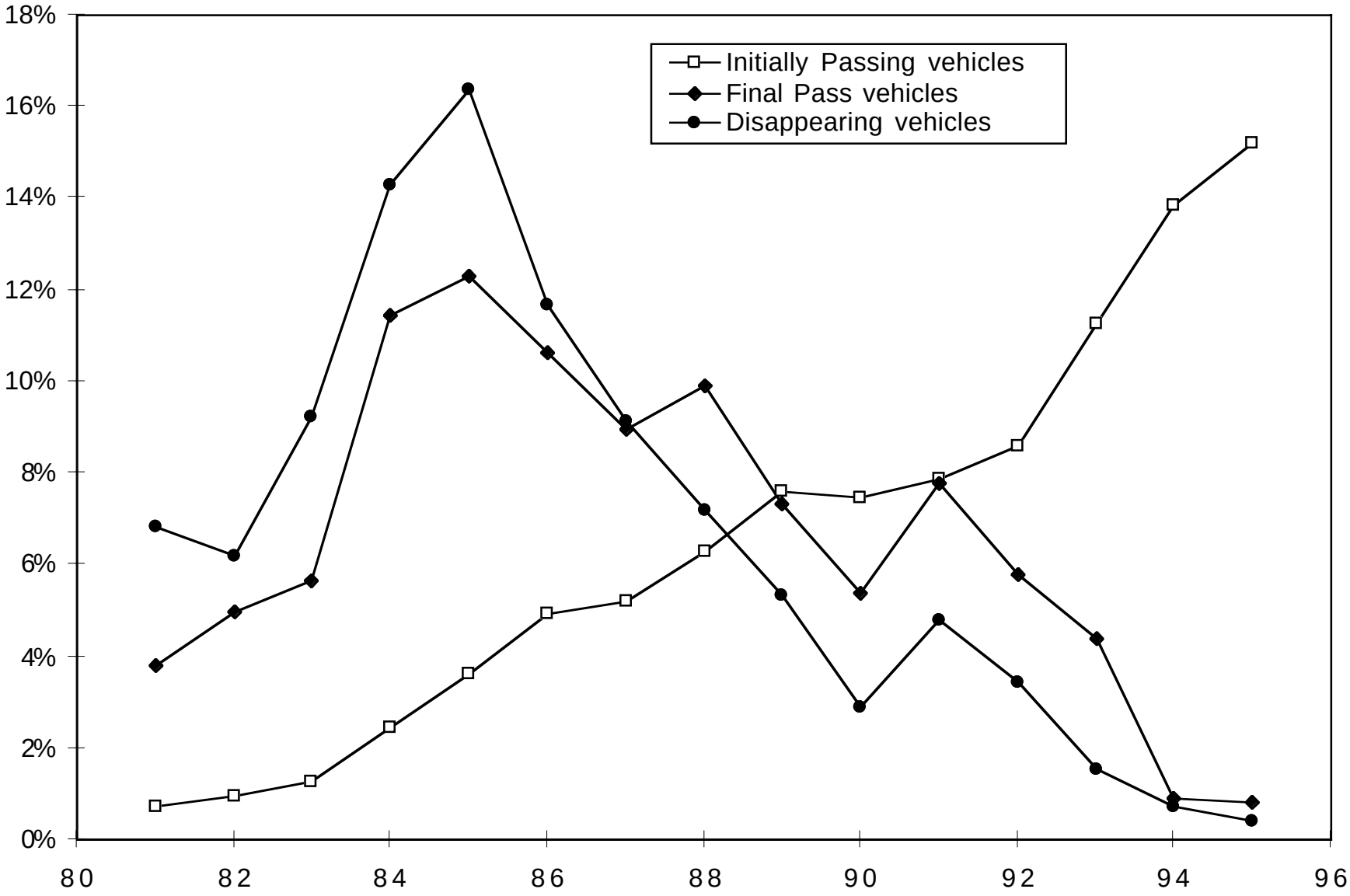


MY Distribution of Vehicles Doesn't Change over Time

- **Large numbers of both Final Pass and Disappearing vehicles are no longer being driven in the I/M area; are the oldest vehicles moving out of the I/M area?**
- **Used the remote sensing data to compare the distribution of vehicles by MY, both soon after I/M testing and over 15 months after I/M testing**
- **The MY distributions are quite similar, indicating that vehicles of all model years are relocating out of the I/M area**

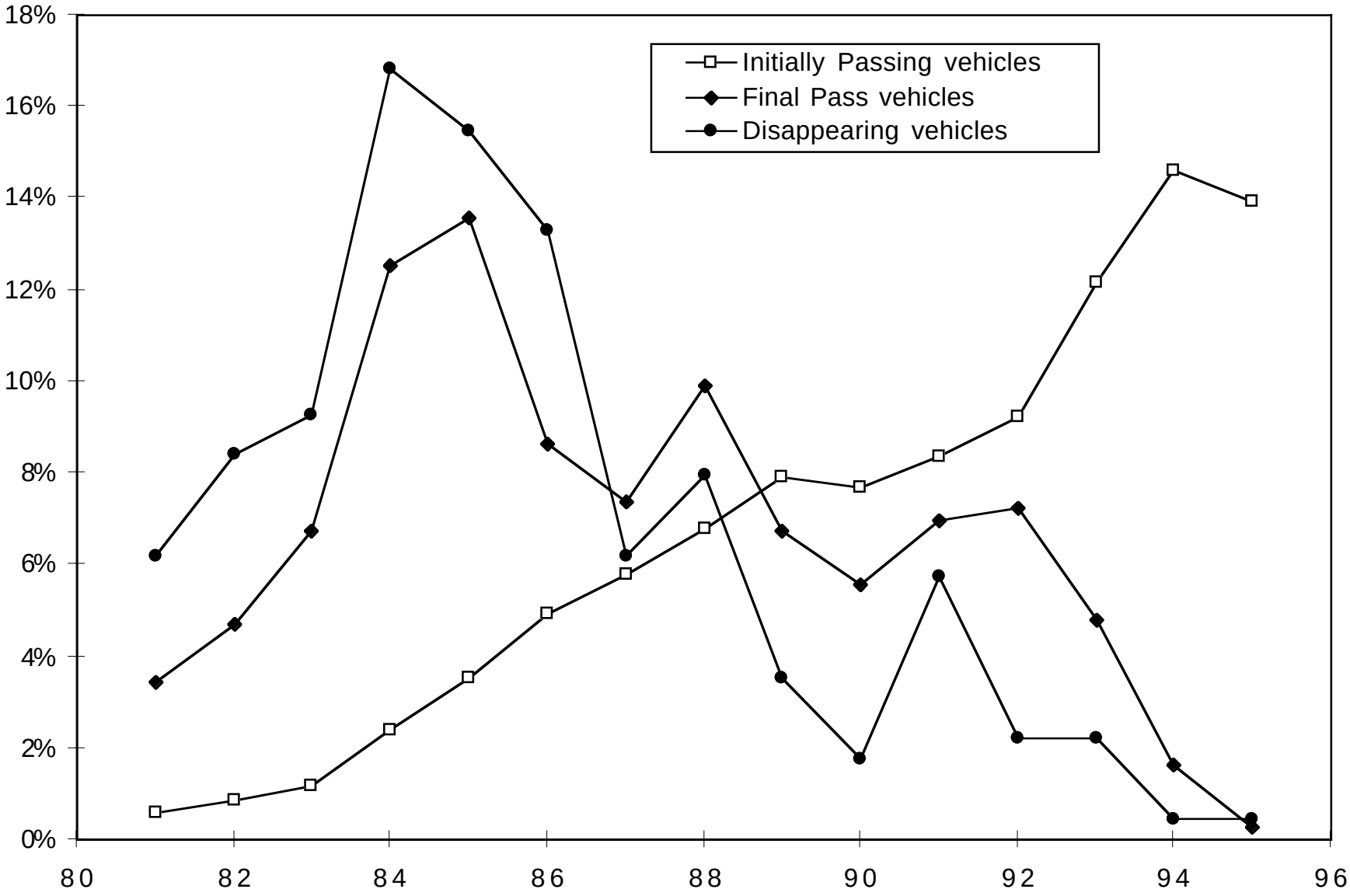
Distribution of Vehicles by MY and I/M Result

Less than 1 month after initial IM240, 1996-97 Arizona Remote Sensing



Distribution of Vehicles by MY and I/M Result

Over 15 months after initial IM240, 1996-97 Arizona Remote Sensing

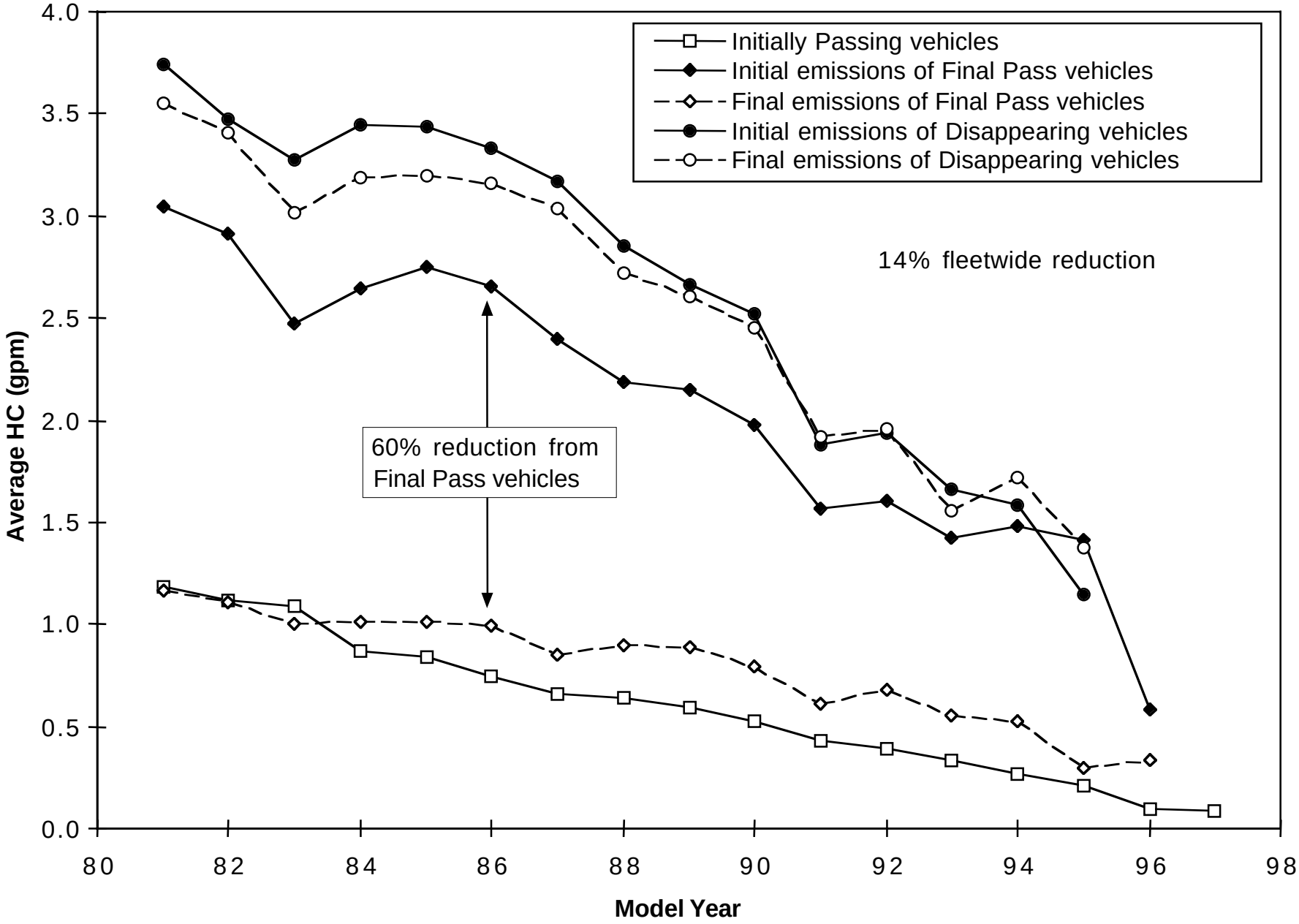


Summary

- An independent source of data, either remote sensing or roadside emissions testing, is needed to evaluate effectiveness of I/M programs
- Initial CO emissions reductions from Arizona IM240 program are comparable to those predicted by MOBILE5; MOBILE5 slightly overpredicts initial reductions in HC, and dramatically overpredicts initial reductions in NOx
- Remote sensing data show initial repair effectiveness comparable to IM240 data, after accounting for different vehicle operation
- Remote sensing data show that about half of the fleet emission reductions measured by IM240 are lost one year after I/M testing; subsequent IM240 data confirm this result. Much of this loss in emission reduction comes from repeat failures by the same vehicles
- Disappearing vehicles that never pass the IM240 are still being driven in the I/M area; these vehicles are from all model years

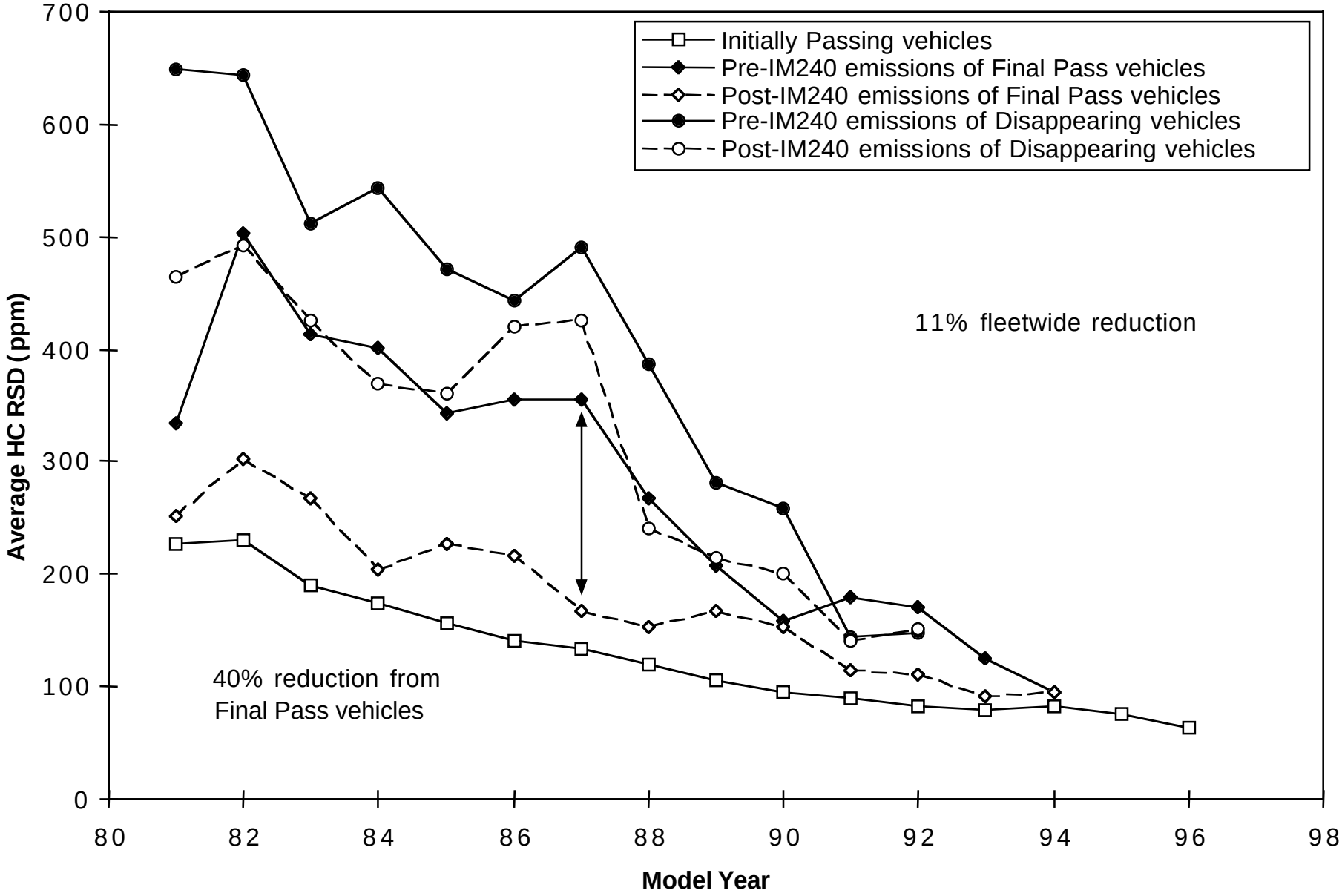
Average HC gpm by MY and I/M Result

1996-97 Arizona IM240



Average RSD HC by MY and I/M Result

Up to 90 days before and after I/M test, 1996-97 Arizona Remote Sensing



Average HC RSD Emissions by Time Period

1996-97 Arizona Remote Sensing